range was approximately 8% lower (see section 3.2) than we observed in the the 2001-2002 study period, a loss that may account for the lower *T. wasselli* abundance. In 2003-2004, *Scoletoma tenuis* was the second most numerically abundant organism over all habitat types and was among the top five dominant organisms found in open water habitats. There were no significant differences in abundances of *S. tenuis* in tidal creek versus open water habitats in the current study ($p = 0.282$).

SCECAP uses a single multi-metric benthic index of biological integrity (B-IBI) to distinguish between degraded and undegraded environments in southeastern estuaries (Van Dolah *et al*., 1999). A number of metrics (i.e., abundance, number of species, and abundance of sensitive taxa) have been integrated into the B-IBI in order to summarize benthic community condition in coastal habitats. About 70% of South Carolina's open water and 71% of tidal creek habitat sampled in 2003-2004 had a healthy benthic community (Table 3.4.3). There has been an apparent decrease in the amount of habitat supporting healthy benthic communities (ie., coding as good benthic condition) since the initial 1999-2000 survey (open water = 16% decline, tidal creek = 13% decline; Van Dolah *et al*., 2002a, 2004a). The amount of South Carolina's coastal habitat that supported benthic communities having some evidence of possible degradation (ie., coding as fair benthic condition) was approximately 22% in open water habitat and 21% in tidal creek habitats. Both habitat types have shown an increase in the percentage of habitat having only fair benthic community condition since the 1999-2000 study (Table 3.4.3). Approximately 8% of the coastal open water and tidal creek habitat had a poor benthic community condition, which represents an approximate increase by 6% in open water habitat and 4% in tidal creek habitat since the inception of the program.

Table 3.4.3. Percent of habitat with B-IBI values indicating good (undegraded), fair (marginally degraded), or poor (degraded) benthic conditions.

	Percent of Habitat B-IBI					
	Open Water			Tidal Creek		
Study Period	Good	Fair	Poor	Good	Fair	Poor
1999-2000	86	12	2	84	12	4
2001-2002	83	14	3	69	27	4
2003-2004	70	22	8	71	21	8

When evaluating B-IBI scores on a yearly basis, there is clearly a trend of decreasing percentage of coastal habitat which supports healthy benthic communities in South Carolina (Figure 3.4.7), with associated increases in the percentages of coastal habitats which have fair and poor benthic community condition. While we didn't observe similar trends in water quality or sediment quality conditions over the course of the study, there has been an increase in ERM-Q (see section 3.3) in coastal areas. The contribution of rising contaminant levels to the decreasing B-IBI is unclear, particularly considering the concomitant changes in salinity during this time.

Finfish and Crustacean Communities

South Carolina estuaries support a diverse array of fish and crustaceans that are dependent on estuarine habitats for food and shelter (Joseph, 1973; Mann, 1982; Nelson *et al*., 1991). Estuaries represent a naturally stressful environment due to broad fluctuations in physical conditions (temperature, salinity, etc) and biological pressures such as predation and competition with other species. In addition, anthropogenic stressors such as recreational and commercial fishing, boating activity, upland development, storm water inputs, and habitat modifications are all placing additional pressures on South Carolina's essential estuarine habitats. Changes to these coastal ecosystems will ultimately lead to changes in the fish and crustacean communities that are dependent upon them (Monaco *et al*., 1992).

Community Composition:

A total of 14,912 organisms representing 72 species were collected by trawl during the 2003-2004 survey (data online). Mean faunal density across all stations varied from four to 4,790 individuals per hectare (individuals/ha) with an overall average of 714 individuals/ha. The mean density in tidal creeks (1040 individuals/ha) was more than twice the mean density in open water habitats (388 individuals/ha), a statistically significant difference ($p < 0.001$). The trend of higher mean faunal densities in tidal creek

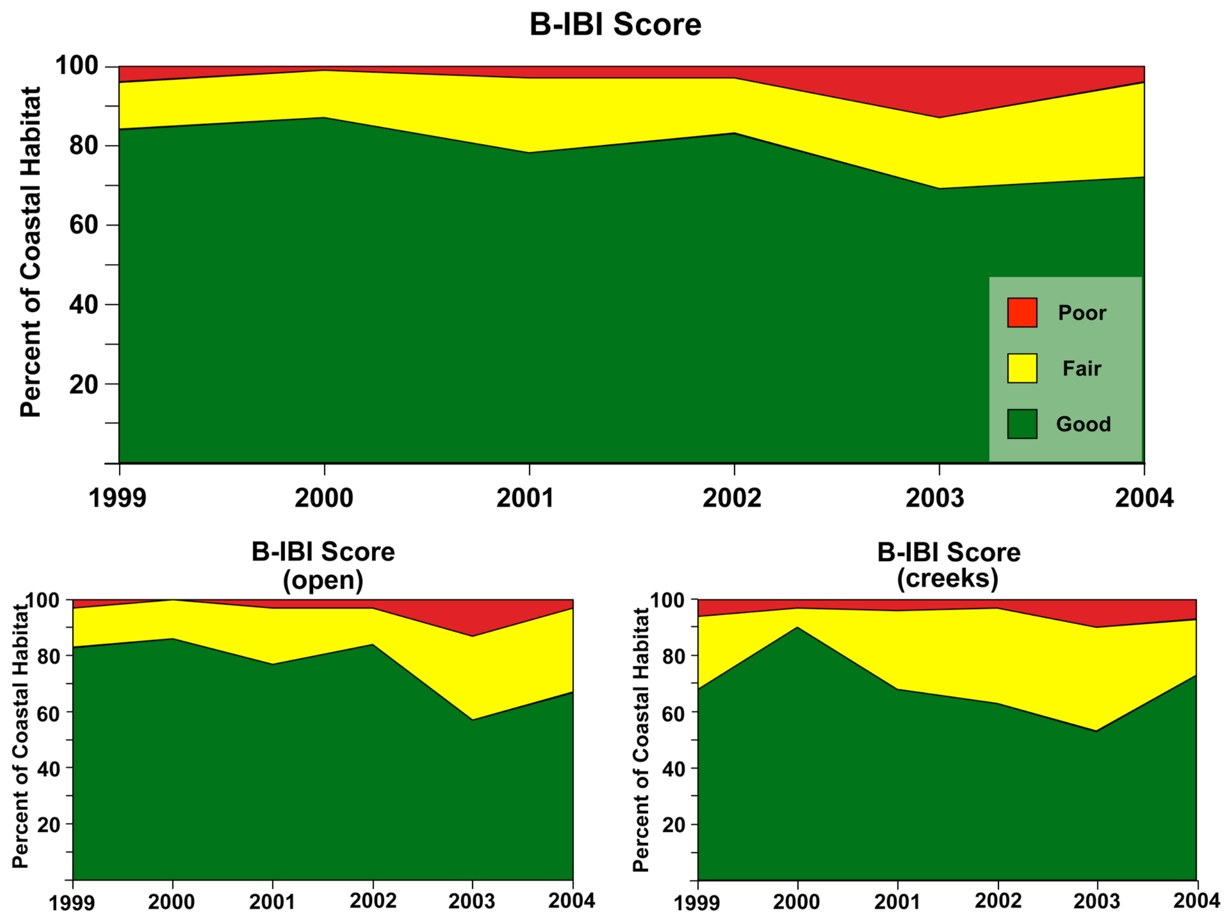


Figure 3.4.7. Proportion of the South Carolina's estuarine habitat that ranks as good (green), fair (yellow) or poor (red) using the benthic index of biological integrity (B-IBI) values compared on an annual basis when tidal creek and open water habitats are combined and for tidal creek and open water habitats considered separately.

stations compared to open water stations has been observed in all three of the survey periods evaluated by SCECAP to date (Van Dolah *et al*., 2002a, 2004a).

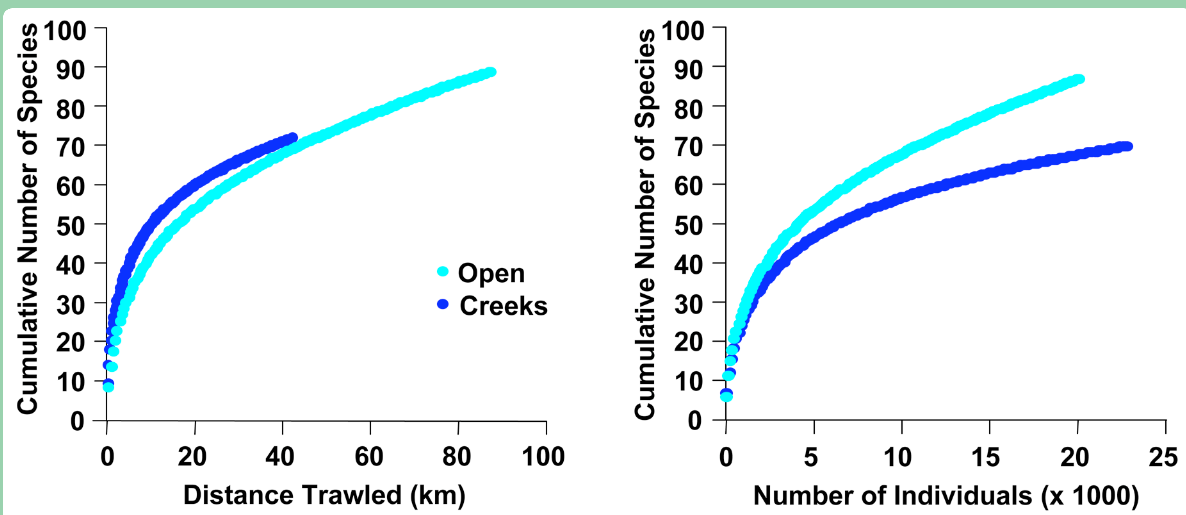
The average number of species collected across all stations was 5.9 and varied from 1 to 15 per trawl. Evenness values (J') averaged 0.66 and varied from 0.00 to 1.00, and overall community diversity (H') averaged 1.62 and varied from 0.00 to 2.96. The mean number of species per trawl was slightly higher in tidal creek habitat than in open water habitats (open water = 5.5, tidal creek = 6.4; $p = 0.084$), but J' (open water = 0.68, tidal creek = 0.65; $p = 0.516$) and H' (open water = 1.58, tidal creek = 1.67; $p = 0.502$) were similar. Similar trends were observed for both species numbers and diversity in previous survey periods (Van Dolah *et al*., 2002a, 2004a). While the number of species appears to be greater in tidal creek habitats, it is actually likely to be much greater in open water habitats (Box 3.4.3). Trawls in tidal creeks initially catch more species because fish and crustaceans occur at much higher densities there. However, open water habitats ultimately support more species, likely due to their proximity to the higher salinity open ocean and greater diversity of habitat types. This highlights the different roles filled by these habitats. Productive tidal creek habitats provide forage and nursery habitat for high-density populations of fish and crustaceans, while open water habitats serve as reservoirs of biodiversity.

The 50 most numerically abundant taxa comprised 99.8% of the overall abundance across all stations and included 23 recreationally and/or commercially important species (Table 3.4.4). The five most numerically abundant species were white and brown shrimp (*Litopenaeus setiferus* and *Farfantepenaeus aztecus*), pinfish (*Lagodon*

Box 3.4.3 Large Finfish and Crustacean Biodiversity

How many species of large demersal finfish and crustaceans use South Carolina's estuarine environments?

Answering this question requires the application of species-area or species accumulation curves, a technique that examines how rapidly the total number of species captured accumulates as one makes more collections. The graphic below shows the total number of species captured by trawling as a function of the total distance trawled and the total number of individual organisms captured. Notice that because finfish and crustaceans occur at much higher densities in tidal creeks, the number of species caught increases rapidly with trawling effort. However, with further trawling effort, the number of new species caught slows much more than in open water habitats. In open water habitats, the number of new species accumulates more slowly than in tidal creeks at first, but even after having trawled for approximately 90 km, the number of new species is still increasing. By extending these lines out until they become horizontal (to the point at which new species are no longer being captured with additional sampling effort), the total number of species using each habitat can be predicted. Applying this technique, South Carolina's tidal creek habitats are predicted to support approximately 89 large finfish and crustacean species while open water habitat are predicted to support approximately 138.



Species accumulation curves for all six years of SCECAP monitoring.

rhomboides), spot (*Leiostomus xanthurus*), and Atlantic croaker (*Micropogonias undulatus*). These recreationally and/or commercially important species accounted for 80% of all fish and crustaceans captured. Three of the five most numerically dominant taxa collected in 2003-2004 (*L. setiferus, F. aztecus, L. xanthurus*) were also among the five dominant taxa collected in both previous survey periods (Van Dolah *et al*., 2002a, 2004a). In open water habitats, the five most numerically abundant taxa were white shrimp, Atlantic croaker, brown shrimp, spot, and weakfish (*Cynoscion regalis*), species that comprised approximately 72% of the total abundance of fish and crustaceans in this habitat. In tidal creek habitats, the five most numerically abundant taxa were white shrimp, pinfish, brown shrimp, spot, and brief squid (*Lolliguncula brevis*), species that comprised more than 87% of the total abundance in this habitat. White shrimp, the most abundant species in both open water and tidal creek habitats, were found in significantly greater numbers in tidal creek habitats ($p = 0.005$) than in open water habitats. With the exception of

Table 3.4.4. The mean densities (number per hectare) and percent occurrence of the 50 numerically most abundant taxa collected by trawl in tidal creek and open water habitats during 2003-2004. Recreationally-important species are shown in bold text.

		Open Water		Tidal Creek	
Species Name	Common Name	Mean Abundance (#/hectare)	Percent of Stations Where Present	Mean Abundance (#/hectare)	Percent of Stations Where Present
Litopenaeus setiferus	**White shrimp**	125.4	48	569.9	67
Farfantepenaeus aztecus	**Brown shrimp**	42.7	62	97.6	73
Lagodon rhomboides	**Pinfish**	21.0	23	104.5	58
Leiostomus xanthurus	**Spot**	36.2	67	83.1	75
Micropogonias undulatus	**Atlantic croaker**	47.8	50	9.4	43
Lolliguncula brevis	Brief squid	16.1	50	38.2	55
Bairdiella chrysoura	**Silver perch**	3.5	32	33.2	53
Cynoscion regalis	**Weakfish**	27.6	37	3.3	22
Stellifer lanceolatus	Star drum	23.0	28	7.6	13
Anchoa mitchilli	Bay anchovy	6.6	33	17.9	48
Trinectes maculatus	Hogchoker	5.9	42	13.3	42
Callinectes sapidus	**Blue crab**	3.0	27	14.5	43
Chaetodipterus faber	**Atlantic spadefish**	2.6	23	6.8	25
Selene vomer	Lookdown	6.0	23	3.3	22
Callinectes similis	Lesser blue crab	2.8	15	3.7	25
Ictalurus furcatus	**Blue catfish**	0.7	7	5.6	8
Orthopristis chrysoptera	Pigfish	1.3	15	5.0	25
Chloroscombrus chrysurus	Atlantic bumper	2.6	12	1.2	3
Gerreidae	Mojarras	1.0	8	2.3	10
Opsanus tau	Oyster toadfish	0.2	5	2.3	15
Paralichthys lethostigma	**Southern flounder**	0.5	12	1.7	18
Prionotus scitulus	Leopard searobin	2.0	8	0.1	2
Chilomycterus schoepfi	Striped burrfish	0.2	7	1.7	17
Centropristis striata	**Black sea bass**	0.2	3	1.7	3
Stephanolepis hispidus	Planehead filefish	0.6	7	0.9	7
Paralichthys dentatus	**Summer flounder**	0.8	10	0.6	7
Menticirrhus americanus	**Southern kingfish**	0.5	8	0.7	7
Brevoortia tyrannus	Atlantic menhaden	0.2	3	1.1	7
Selene setapinnis	Atlantic moonfish	1.2	2	0.0	0
Dasyatis sabina	Atlantic stingray	0.4	7	0.7	7
Symphurus plagiusa	Blackcheek tonguefish	0.4	10	0.6	8
Citharichthys spilopterus	Bay whiff	0.2	5	0.7	10
Gymnura micrura	Smooth butterfly ray	0.1	3	0.7	7
Menticirrhus sp.	**Kingfish**	0.5	8	0.2	3
Peprilus alepidotus	Harvestfish	0.7	5	0.0	0
Lepisosteus osseus	longnose gar	0.0	0	0.6	7
Prionotus tribulus	Bighead searobin	0.6	10	0.0	0
Anchoa hepsetus	Striped anchovy	0.4	8	0.1	2
Farfantepenaeus duorarum	**Brown-spotted shrimp**	0.1	2	0.5	3
Etropus crossotus	Fringed flounder	0.0	0	0.5	5
Mugil cephalus	**Striped mullet**	0.0	0	0.5	5
Synodus foetens	Inshore lizardfish	0.0	0	0.5	5
Centropristis philadelphica	Rock sea bass	0.0	0	0.5	5
Dasyatis sayi	Bluntnose stingray	0.4	5	0.0	0
Rhizoprionodon terraenovae	**Atlantic sharpnose shark**	0.3	7	0.1	2
Cynoscion nebulosus	**Spotted sea trout**	0.0	0	0.4	3
Archosargus probatocephalus	**Sheephead**	0.1	2	0.2	2
Scomberomorus maculatus	**Spanish mackerel**	0.1	3	0.1	2
Ictalurus catus	**White catfish**	0.0	0	0.2	2
Lepomis sp.		0.0	0	0.2	2
Pomatomus saltatrix	**Bluefish**	0.0	0	0.2	2

Atlantic croaker, the abundance of the other dominant organisms was also significantly greater in tidal creek habitats than in open water habitats.

There are currently no formal indices of estuarine habitat condition applicable to the southeastern US using large crustacean and fish communities. However, using percentiles, areas supporting unusually low crustacean and fish densities and biodiversities can be identified. The 10th, 25th and 50th percentiles of mean densities, mean species number, and mean community diversity (H') in open water and tidal creek habitats are presented in Table 3.4.5. Two open water stations and two tidal creek stations (RO036057, RO046070, RT042064, and RT042070) fell below the 10th percentile for each of these metrics. Based on the overall integrated measure of habitat quality (Appendix 2), only RT042070 was coded as not having good habitat quality. Located on a tributary of the Cooper River upriver from Grove Creek in the Charleston area, this station had only a fair overall habitat quality score, with a good water quality score, but fair condition for sediment quality and poor for benthic community condition.

Recreationally and Commercially Important Species:

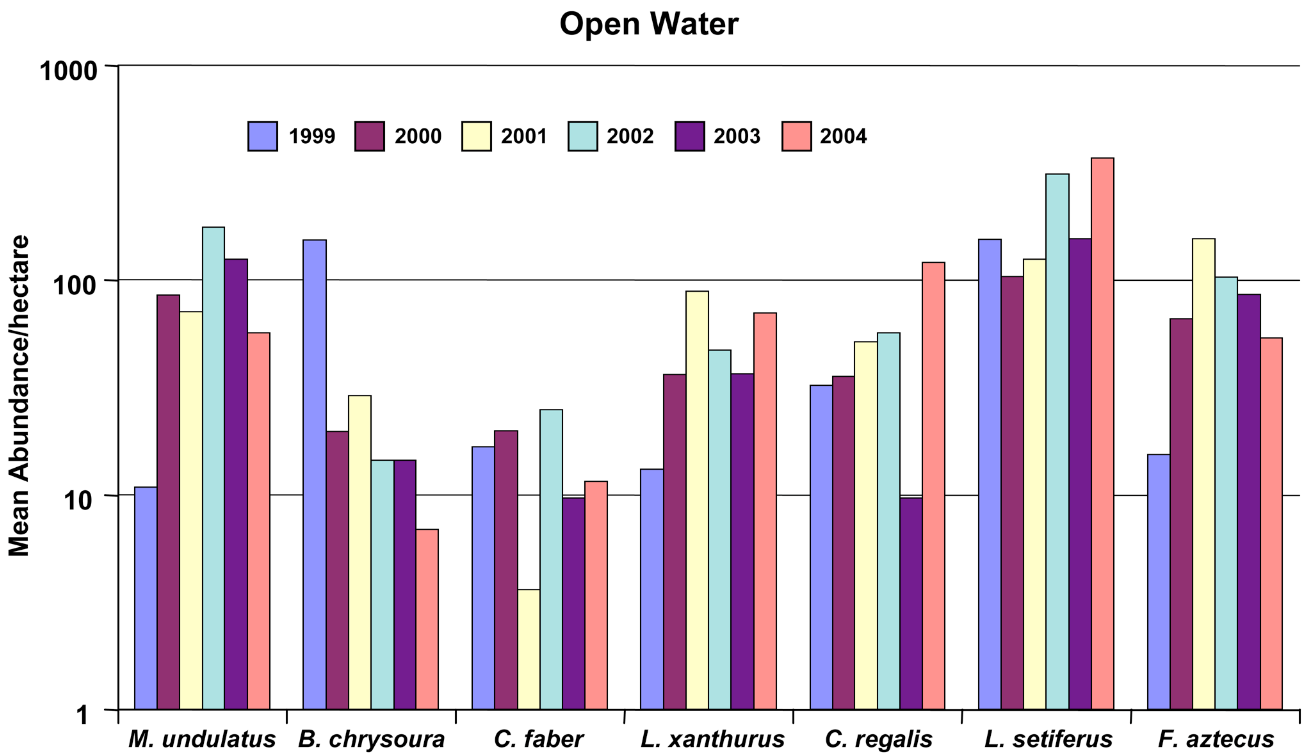
Recreationally and commercially important fish and crustaceans collected during the 2003-2004 sampling season included 23 species and accounted for 88% of the total abundance of organisms in the trawls (Table 3.4.4; data online). During the 1999-2000 and 2001-2002 survey periods, these taxa comprised 75% and 84% of the total abundance, respectively. Recreationally and commercially important taxa were significantly more abundant in tidal creek habitats (average = 935 indiv/ha) than in open water habitats (314 indiv/ha) during the 2003-2004 survey period ($p = 0.013$). A significantly greater number of recreationally or commercially important species also were found in tidal creek habitats (4.0 species per trawl) than in open water habitats (3.2 species/trawl; $p = 0.005$) even though the trawls in tidal creeks were half the length of those in open water habitats (0.25 km vs. 0.50 km).

The mean densities of selected species over the six-year period from 1999 to 2004 do not suggest any consistent pattern of increase or decline across the various species assessed (Figure 3.4.8). In open water habitats, white shrimp, weakfish, and spot showed slightly increasing abundance over time. In tidal creek habitats, white shrimp also showed a slight increase in abundance while weakfish and brown shrimp showed slight decreases in abundance.

Since SCECAP started in 1999, the program has provided a source of fisheries-independent monitoring for species which are not otherwise monitored by SCDNR. These include several commercially and recreationally important fish species such as spot, weakfish, and Atlantic croaker. Changes in bag and size limits have been advocated recently for several species including weakfish. Our knowledge of the distributions and population dynamics of several of these species remains incomplete and the data collected by this monitoring program could help to fill some of the existing gaps. The SCECAP database also provides critical information on the distributions and population structures of many fish and invertebrates

Table 3.4.5. Mean values and the 10th, 25th, and 50th percentiles for density (individuals/hectare), number of species and overall community diversity (H') values for open water and tidal creek habitats.

	Density		Number of Species		Overall Community Diversity (H')	
	Open	Tidal	Open	Tidal	Open	Tidal
Mean	389	1042	5.6	6.5	1.58	1.67
10th percentile	36	186	2.5	3.0	0.72	0.78
25th percentile	73	288	3.0	4.9	1.13	1.20
50th percentile	197	485	5.3	6.8	1.55	1.73



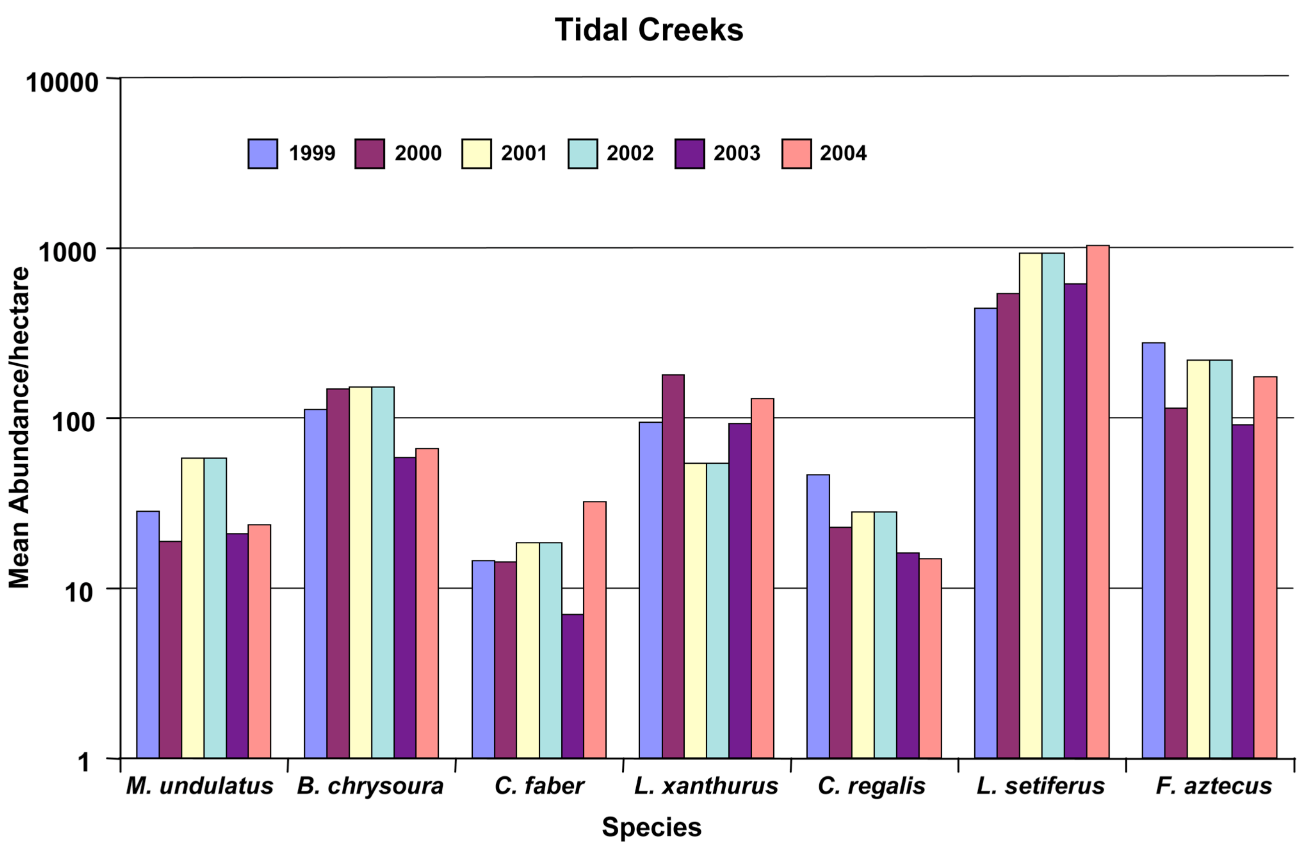


Figure 3.4.8 Mean abundances (number per hectare) of common commercially and recreationally-important fish and crustacean species in open water and tidal creek habitats between 1999 and 2004.

*Table 3.4.6 Priority Species for the South Carolina State Comprehensive Wildlife Conservation Plan that have been captured during the six years of SCECAP monitoring. * = species infrequently caught.*

Marine Fish	Marine Invertebrates
Atlantic Spadefish	Brief Squid
Bay Anchovy	Horseshoe Crab*
Atlantic Croaker	Lined Seahorse*
Kingfish	Stone Crab*
Southern Flounder	
Spot	
Tonguefish	
Crevalle Jack*	
Mummichog*	
Sheepshead*	
Striped Mullet*	

identified as "Priority Species" for the South Carolina State Comprehensive Wildlife Conservation Plan (Table 3.4.6). While other SCDNR programs provide data on some of these species, SCECAP remains the only source of information on many others.

Body Size:

The estuaries of South Carolina serve as nursery habitats for many estuarine and coastal species. Juvenile spot, Atlantic croaker, and penaeid shrimp often numerically dominate tidal creek habitats. An analysis of the length of spot, brown shrimp, and white shrimp from 2001-2004 generally supports this trend. Spot and white shrimp, two of the three most abundant species in both habitats, were significantly larger in open water habitats vs. tidal creek habitats ($p=0.002$ and $p<0.001$ respectively). The size of brown shrimp was not significantly different between the habitat types. However, brown shrimp spawn earlier in the year than do white shrimp, so by the time this program begins sampling (late June), the brown shrimp are fairly large and have begun to move from tidal creek habitats into open water habitats.

Tissue Contaminants:

Human activities can result in the release of contaminants (PAHs, heavy metals, PCBs and pesticides) into estuaries. These chemical compounds can accumulate in estuarine fauna through direct contact with contaminated water and sediments and can be transferred up the food chain from prey to predator. In order to evaluate the level of contamination of estuarine fauna in South Carolina, SCECAP monitors the levels of 93 different contaminants in the tissues of trawled fish. While these values do not necessarily indicate direct human health threats, they do provide a useful index of what contaminants are entering the estuarine food web and where estuarine fauna are most likely exposed to them. In general, the fish collected by SCECAP are small (mean = 10 cm in length), so whole fish are processed rather than just the fillets. The whole body contaminant data collected by SCECAP is an environmental measure of contaminants in fish tissues and should not be directly compared to edible tissue concentrations (fillets only) often used as a measure of risk to humans. Use of whole fish may underestimate the concentration of some contaminants (e.g., mercury) in edible tissue, but provides a better estimate of overall contaminant concentration in the organism.

For the 2003 and 2004 sampling periods, fish tissues were collected at 48 and 35 stations, respectively. The target species were spot (*Leiostomus xanthurus*) and croaker (*Micropogonias undulatus*), both benthic feeders with similar life histories in South Carolina estuaries. Between 2000 and 2003, other species such as pinfish were substituted when the target species were not collected in sufficient quantities. During 2004, tissue samples were taken only for spot and croaker, thus fewer stations had tissue contaminant data in 2004 relative to previous years.

Overall, the level of contamination of young spot and croaker in South Carolina estuaries is low (data online). Therefore, statistical analyses were performed on "total" values, the sums of all the analytes within each class (metals, PAHs, PCBs, and pesticides) for each station. Total metals in fish tissues showed a general trend of higher values in tidal creek habitats than in open water habitats, but total PAHs, total PCBs and total pesticides showed no significant difference between habitat types. Analyses of total contaminant values by year suggested only minimal changes from one year to the next and no generally increasing or decreasing trends across years. When comparing total contaminant values by station, only one station

(RT042079) had a maximum value for total metals that was greater than total metal values at stations found in previous survey periods (2000-2002).

Stations where individual contaminant concentrations in fish tissue exceeded the 90^{th} percentile for tissue contaminants in the 2000-2002 SCECAP data set were also evaluated to identify potentially contaminated habitats. The number of contaminants that exceeded the 90^{th} percentile were counted at each station, and stations were ranked based on the number of exceedences. Due to changes in the method detection limits for PAHs, these contaminants were left out of this analysis. Exceedence values ranged from zero (no contaminants exceeded their respective 90^{th} percentile value) to 14 exceedences at station RT042194 in the upper Ashley River. Of the six random stations that had 7 or more exceedences, four of the stations were in suburban or urbanized rivers: RO036054 in Winyah Bay, RT042194 and RT032046 in the Ashley River, and RO046087 in the Beaufort River. The distribution of contaminated fish tissue in 2003-2004 was similar to previous survey periods where the most highly contaminated fish were caught in suburban and urban rivers such as the Ashley River and the upper part of Winyah Bay.

3.5 Incidence of Litter

Solid waste products, or litter, represent an inevitable consequence of human presence in natural systems. As development and recreational and commercial activities continue to increase in South Carolina's coastal zone, the amount of litter entering our estuaries, flushing into the open ocean, and washing up on beaches is expected to increase.

During 2003 and 2004, litter was visible in 13% of the state's tidal creek habitat and 3% of state's open water habitat. This represented a decrease since the 2001-2002 survey period (during which 20% of tidal creek and 8% of open water habitat had litter), but litter remained elevated well above the 1999-2000 levels (2% of tidal creek and 3% of open water habitat). Generally, the greater percentages of tidal creek sites having litter relative to open water sites likely reflects the closer proximity of tidal creeks to human populations as well as the presence of shoreline, vegetation and oyster reefs that can retain litter within the viewing distance of the survey crews. The reduction in litter over the previous survey period may reflect the flushing of litter out of our estuaries by increased freshwater inflow or just normal variability among survey periods. Considering the year-to-year variability, additional monitoring will be necessary to determine long term trends in litter.

3.6. Integrated Measures of South Carolina's Estuarine Habitat Quality

SCECAP is unique compared to most state and federal monitoring programs because it combines integrated measures of water quality, sediment quality, and biological condition into an overall measure of habitat quality at each site and for the entire coastal zone within its coverage area. Multi-metric measures provide a more reliable assessment than any single measure or group of measures representing only one component of the habitat. For example, poor or fair water quality based on state standards or historical data may not result in any clear evidence of impaired biotic communities. Many of South Carolina's state water quality standards are intentionally conservative to be protective and some contraventions of these standards are not severe enough to result in biological impairment. Similarly, fair or poor sediment quality may not result in degraded biotic condition because the organisms are either not directly exposed to the sediments (e.g., phytoplankton, fish) or because the contaminants are not readily bioavailable to the organisms. When two or more of the three measures (e.g., water quality, sediment quality, or biotic condition) are only fair or poor, there is increased certainty that the habitat may be limiting. While several studies have use a "triad" approach to measuring bottom sediment quality (e.g., Chapman, 1990; Chapman *et al.*, 1991), very few programs have been established elsewhere that use a more holistic approach that includes water quality variables. The USEPA National Coastal Assessment Program is the most successful federal program to use an approach similar to SCECAP, although the habitat metrics and method of integrating those metrics are very different (USEPA, 2001, 2004).

The overall index of habitat quality currently used by SCECAP is described by Van Dolah *et al.* (2004a, available online). This index weights each